

# Upper Tropospheric Water Vapor and Cloud Variations in Observations and Models

Hui Su<sup>1</sup>

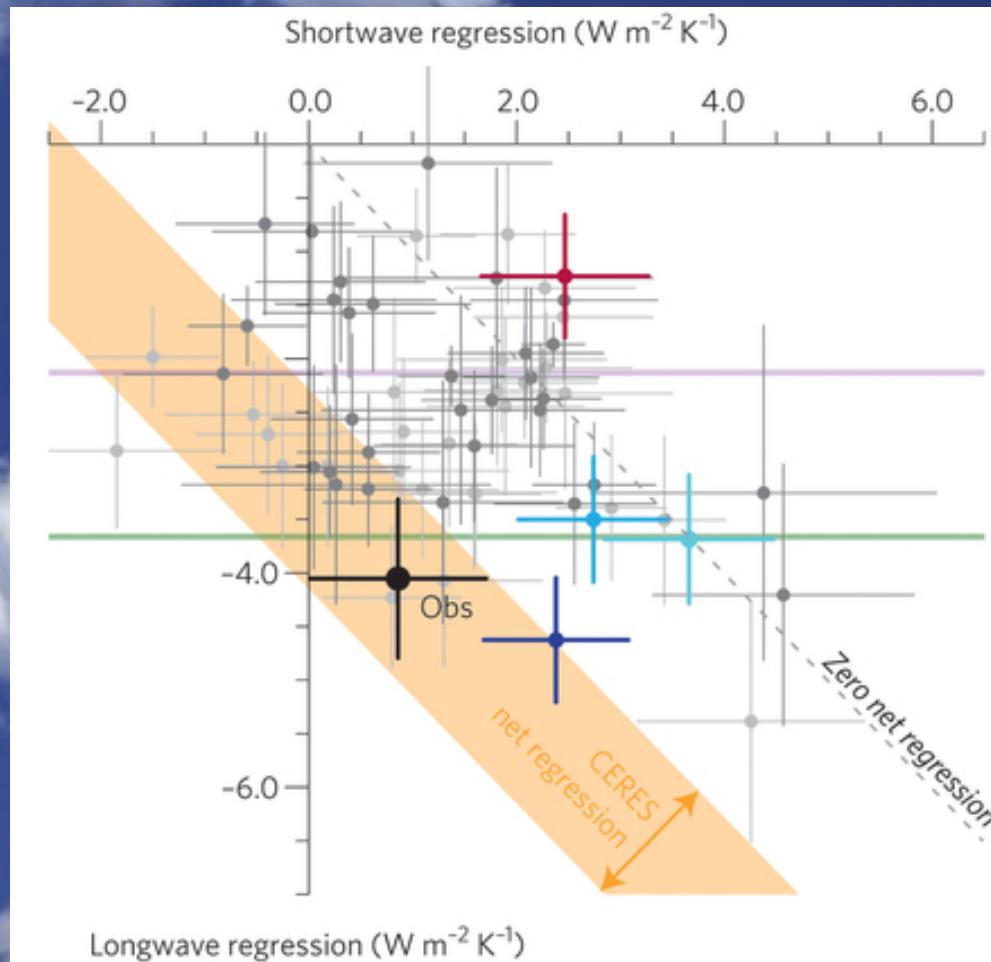
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# “Missing Iris Effect”



The greater reduction of high-level clouds with surface warming in ECHAM6 leads to stronger longwave cooling, lower equilibrium climate sensitivity and higher hydrological sensitivity (Mauritsen and Stevens, 2015, *Nature Geo*).

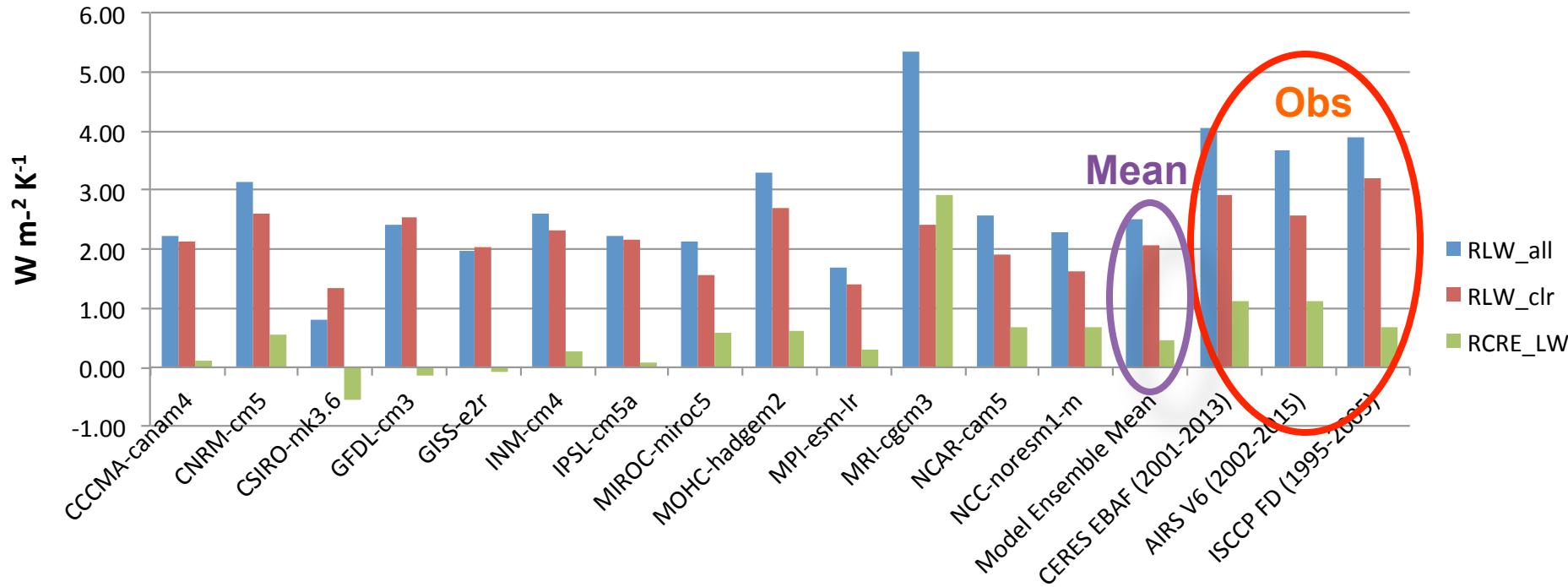
# Questions

- How do upper tropospheric (UT) water vapor and cloud variabilities contribute to the tropical longwave feedbacks in models and observations?
- How are the tropical longwave feedbacks linked to global precipitation sensitivity?

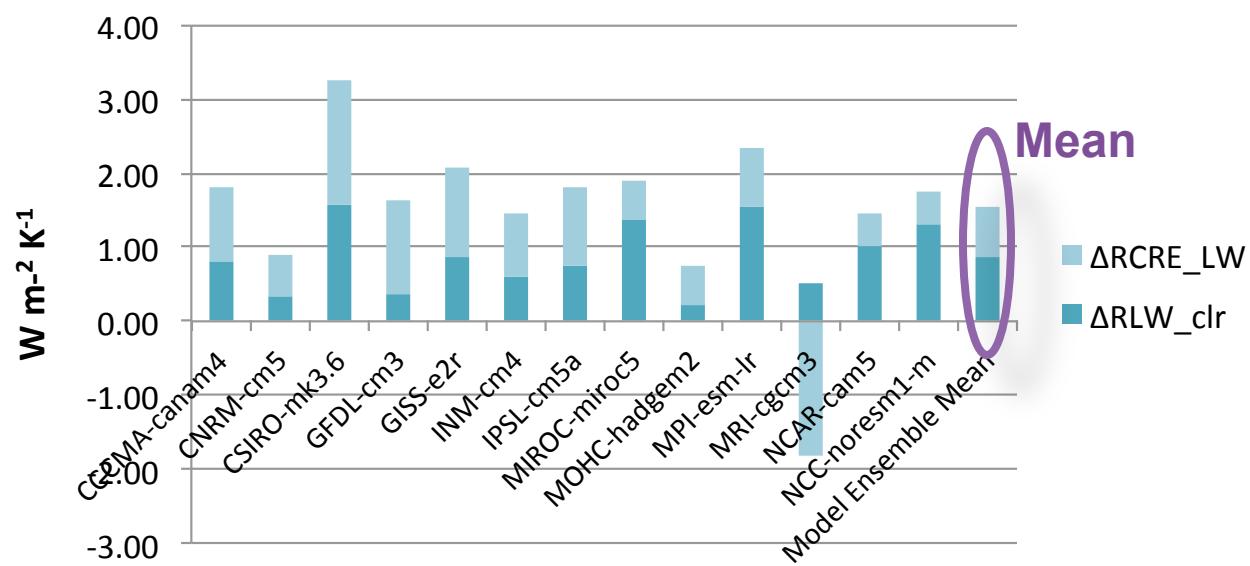
## Data and Models

- CERES-EBAF 2.8 TOA radiative fluxes (January 2001- December 2013)
- GPCP precipitation (1979-2015)
- ISCCP OLR and high cloud fraction (January 1995 to December 2005)
- MODIS high cloud fraction (July 2002 to February 2015)
- AIRS OLR and high cloud fraction (September 2002 to June 2015)
- CloudSat/CALIPSO cloud fraction and cloud class (June 2006 to June 2015)
- MLS UT water vapor (September 2004 to December 2013)
- HadCRUT4 surface temperature ( $T_s$ ) (1979 to 2015)
- 13 AMIP-type model simulations from CMIP5 archive (1995-2005)

# Muted Tropical Longwave (LW) Feedback in Models



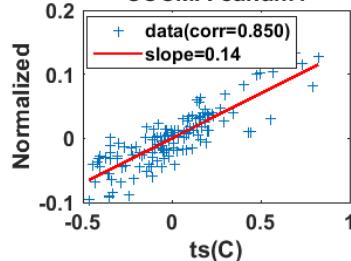
Differences between  
CERES and models  
( $20^{\circ}\text{S}$ - $20^{\circ}\text{N}$ , 1995-2005)



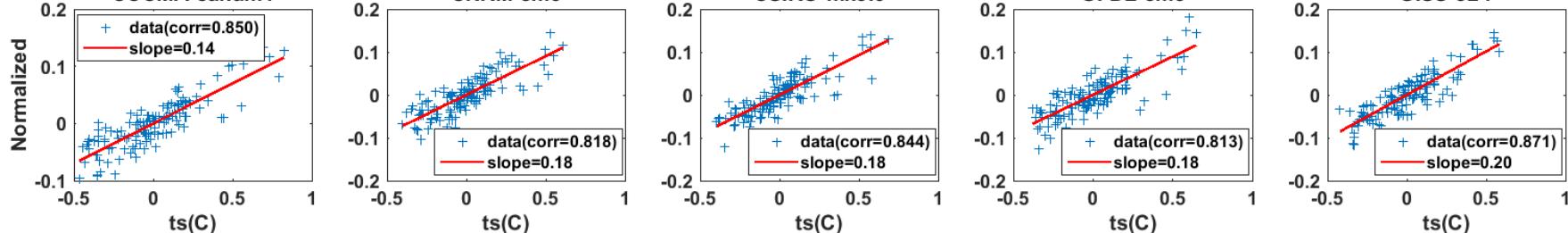
# UT Water Vapor Sensitivity to $T_s$

199501-200512 wvp(250hPaTo100hPa):

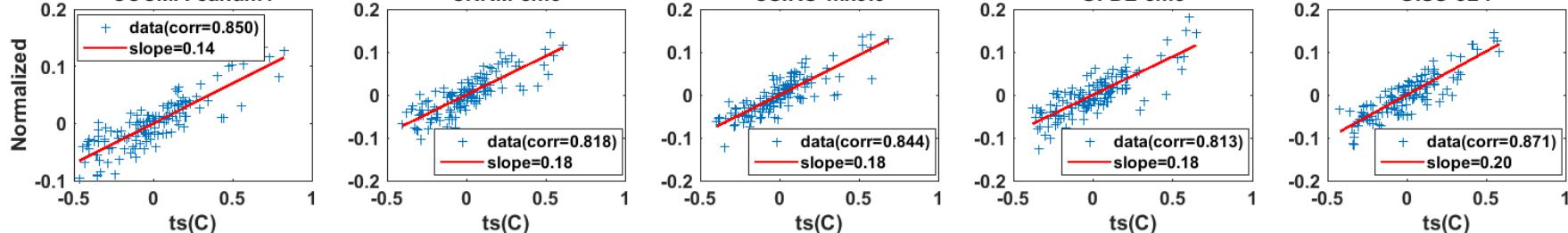
CCCma-canam4



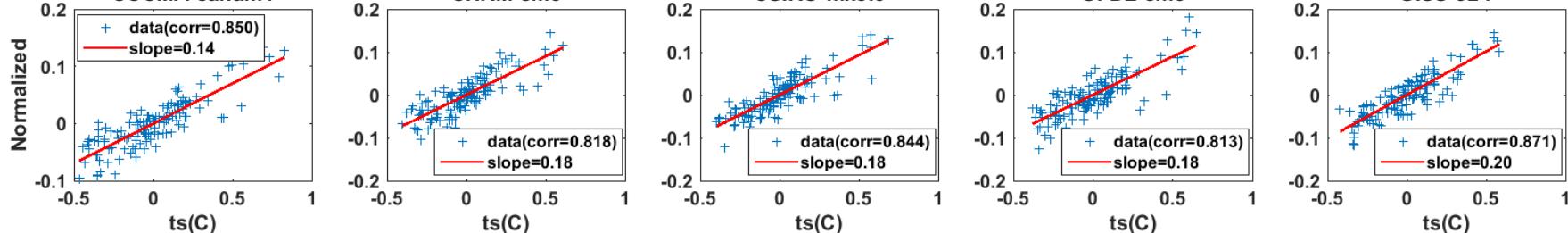
CNRM-cm5



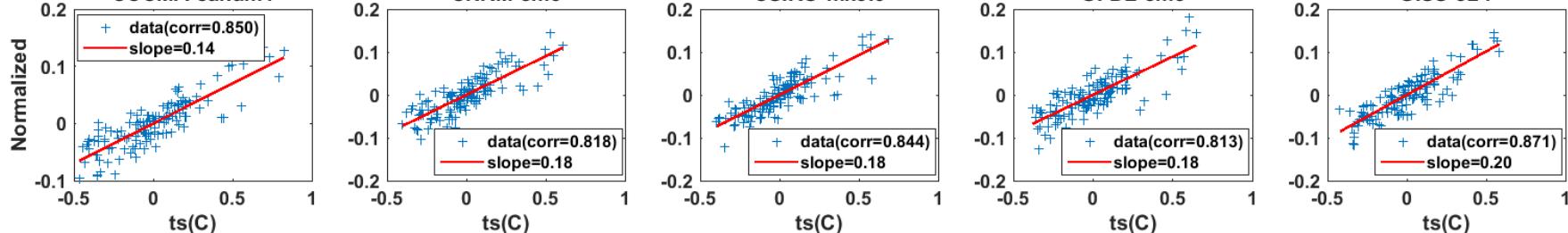
CSIRO-mk3.6



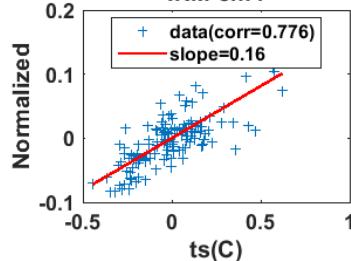
GFDL-cm3



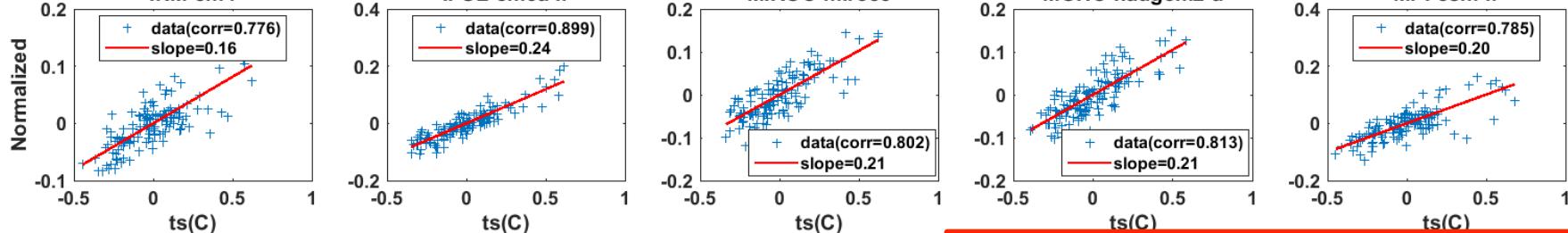
GISS-e2-r



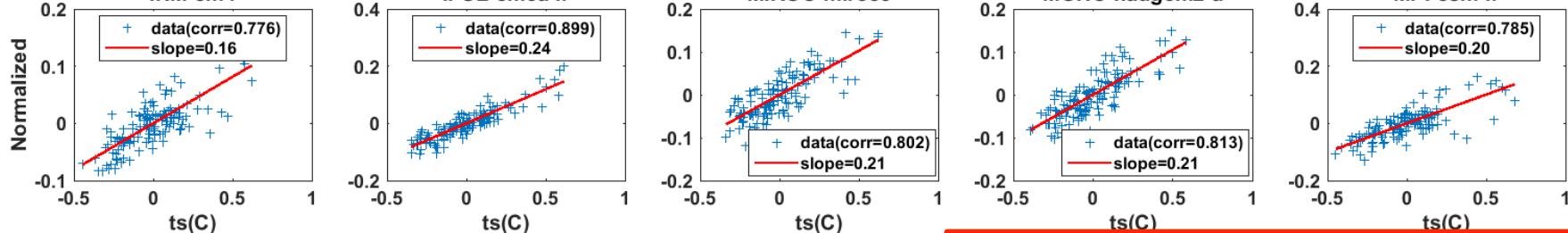
INM-cm4



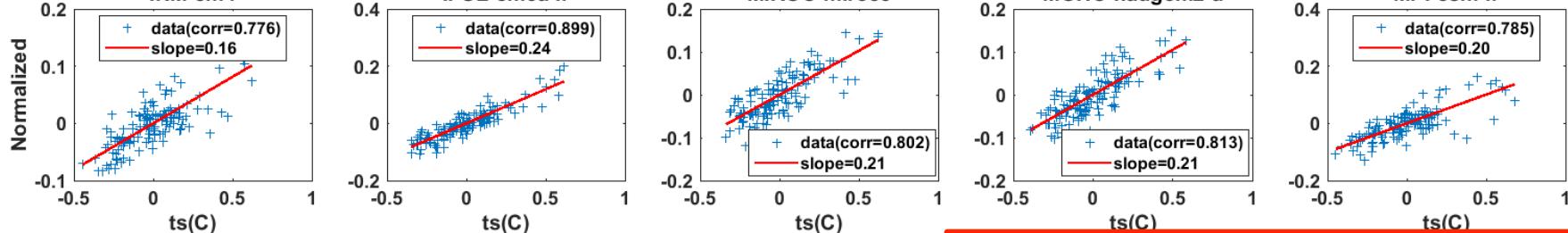
IPSL-cm5a-lr



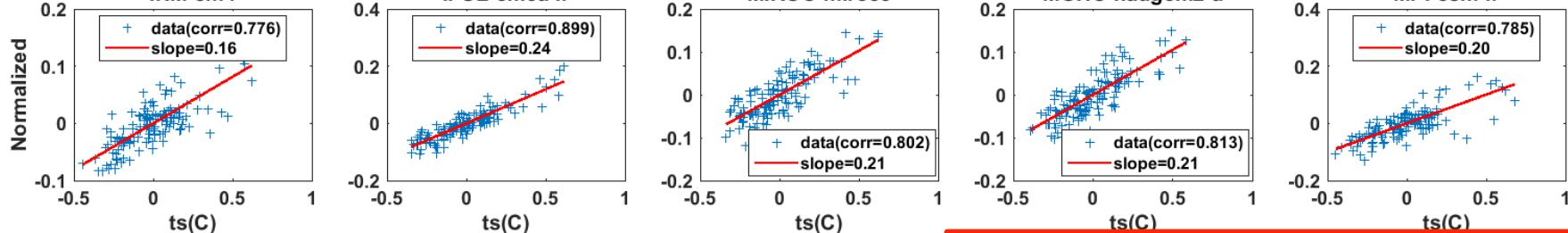
MIROC-miroc5



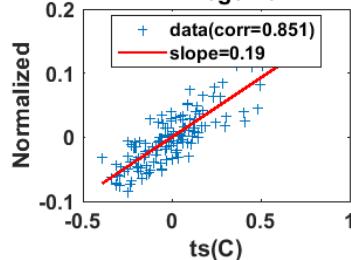
MOHC-hadgem2-a



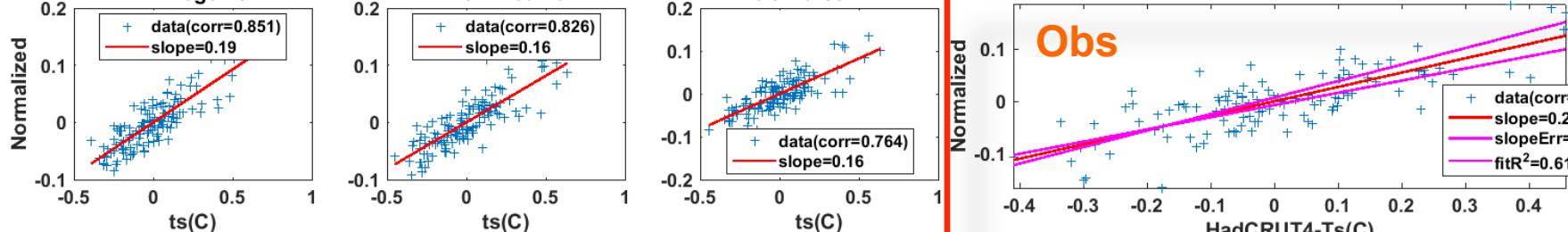
MPI-esm-lr



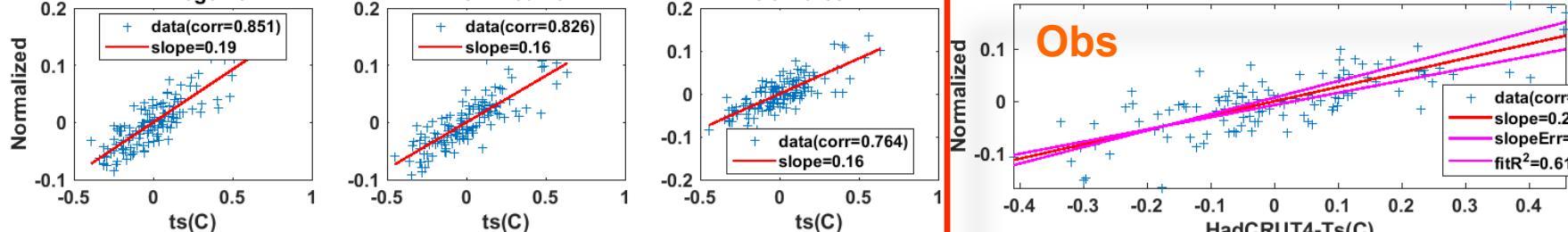
MRI-cgcm3



NCAR-cam5

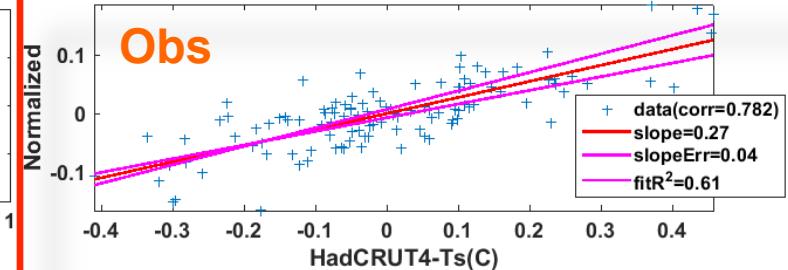


NCC-noresm1-m

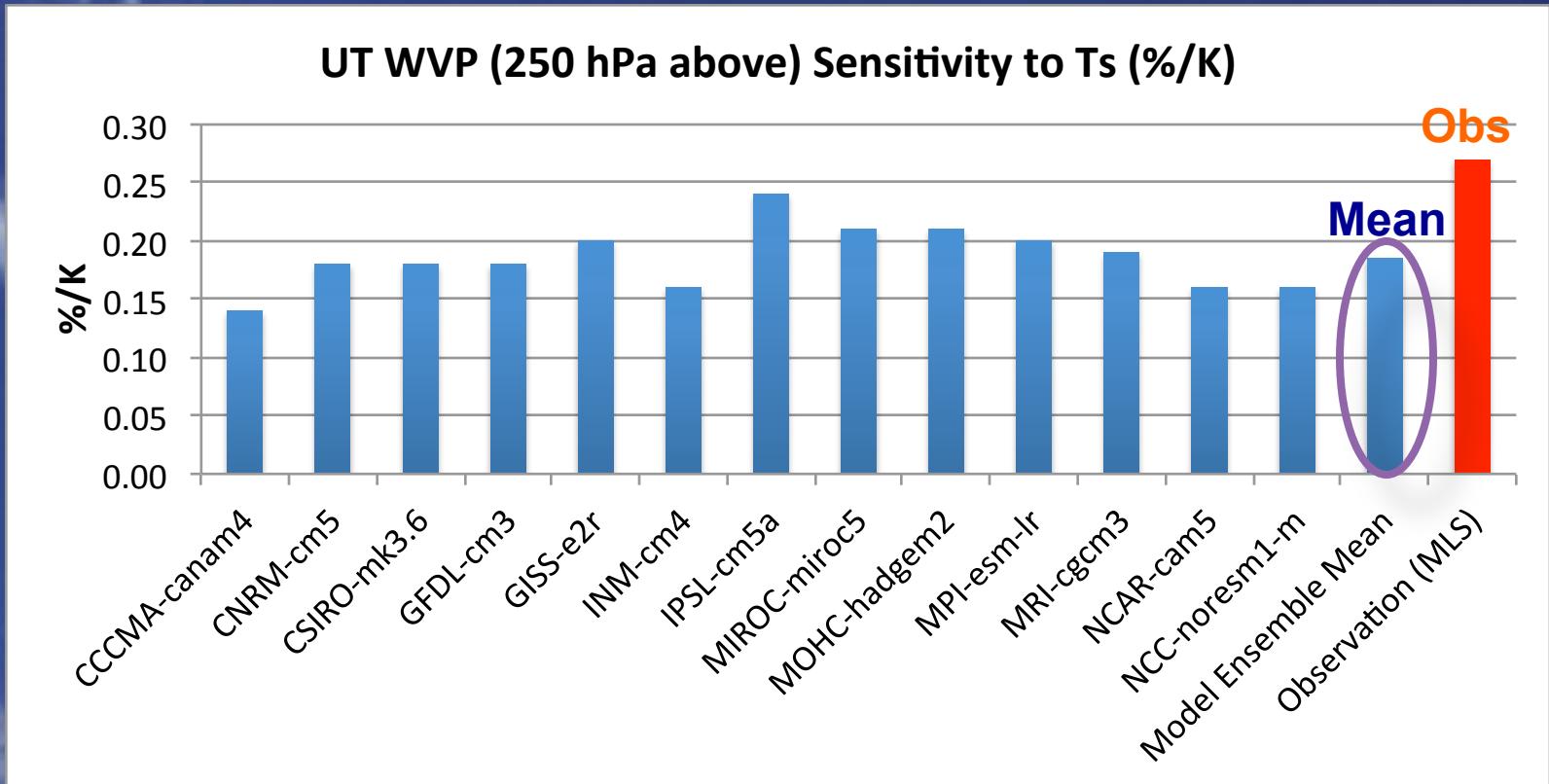


200408-201312MLS wvp 250hPa-100hPa

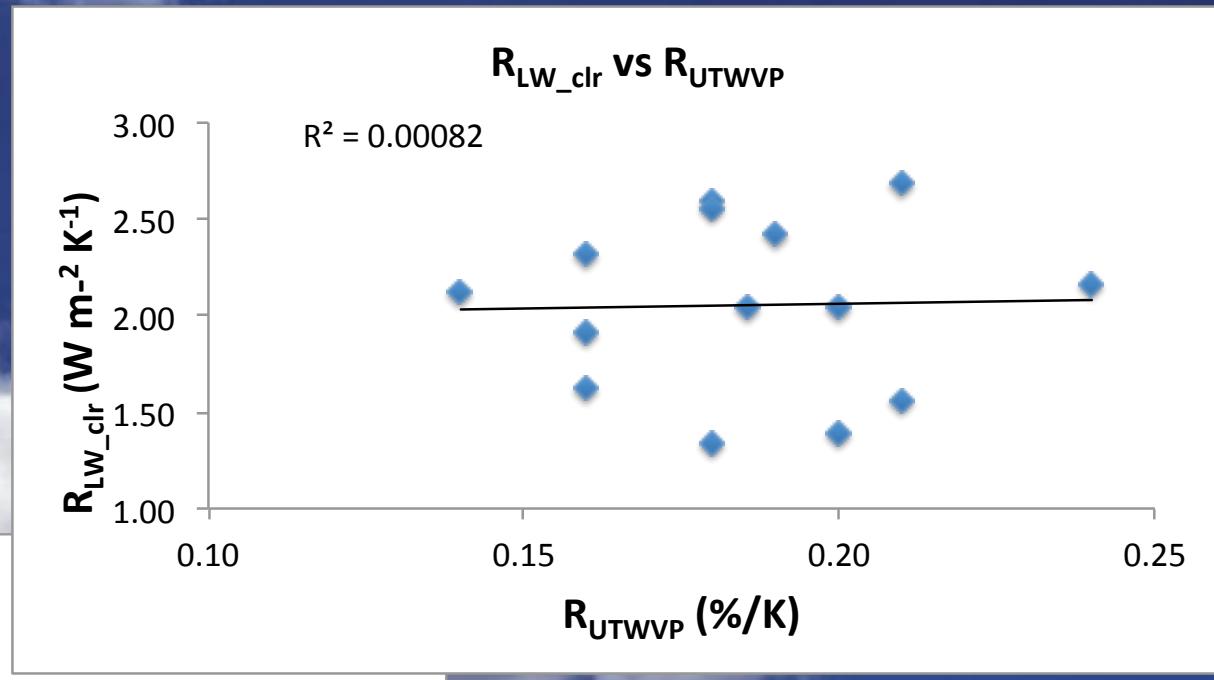
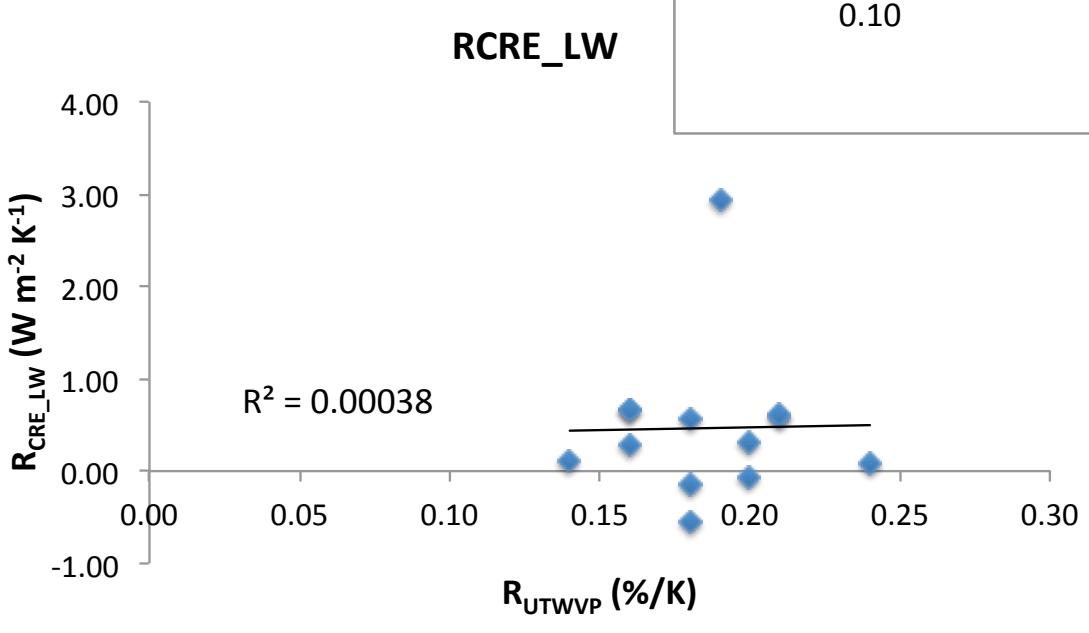
Obs



# Tropical UT Water Vapor Sensitivity to $T_s$



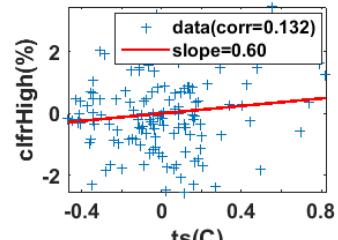
# UT Water Vapor Sensitivity and LW Feedback



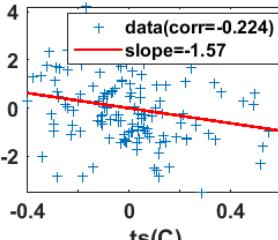
# Tropical High Cloud Fraction Sensitivity to $T_s$

199501-200512 High CloudFraction:

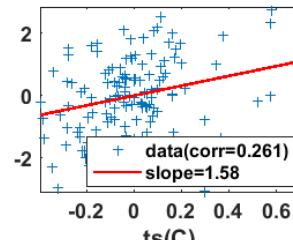
CCCMA-canam4



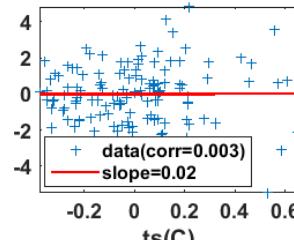
CNRM-cm5



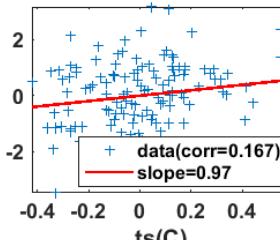
CSIRO-mk3.6



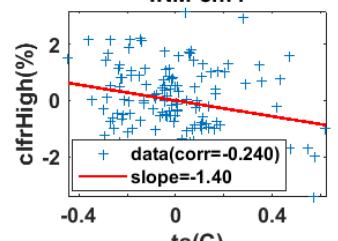
GFDL-cm3



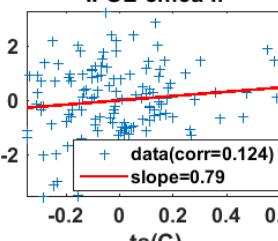
GISS-e2-r



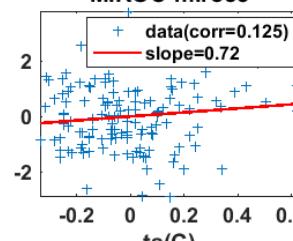
INM-cm4



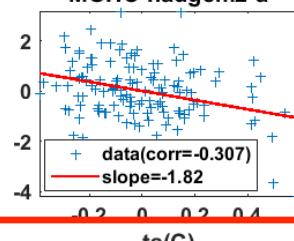
IPSL-cm5a-lr



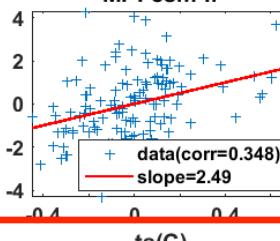
MIROC-miroc5



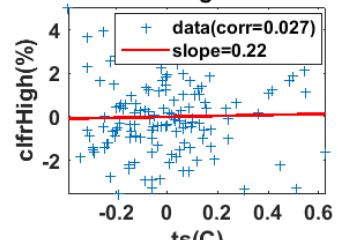
MOHC-hadgem2-a



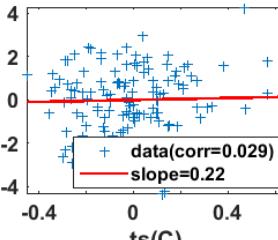
MPI-esm-lr



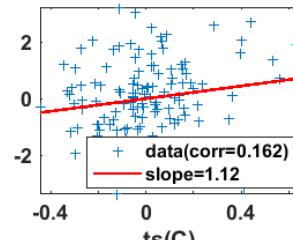
MRI-cgcm3



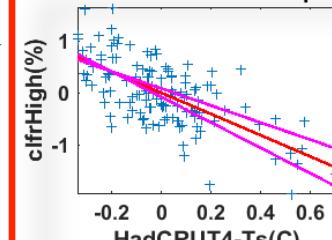
NCAR-cam5



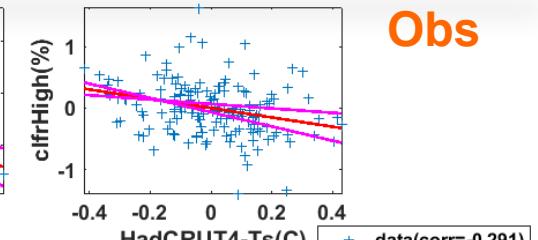
NCC-noresm1-m



199501-200512isccp

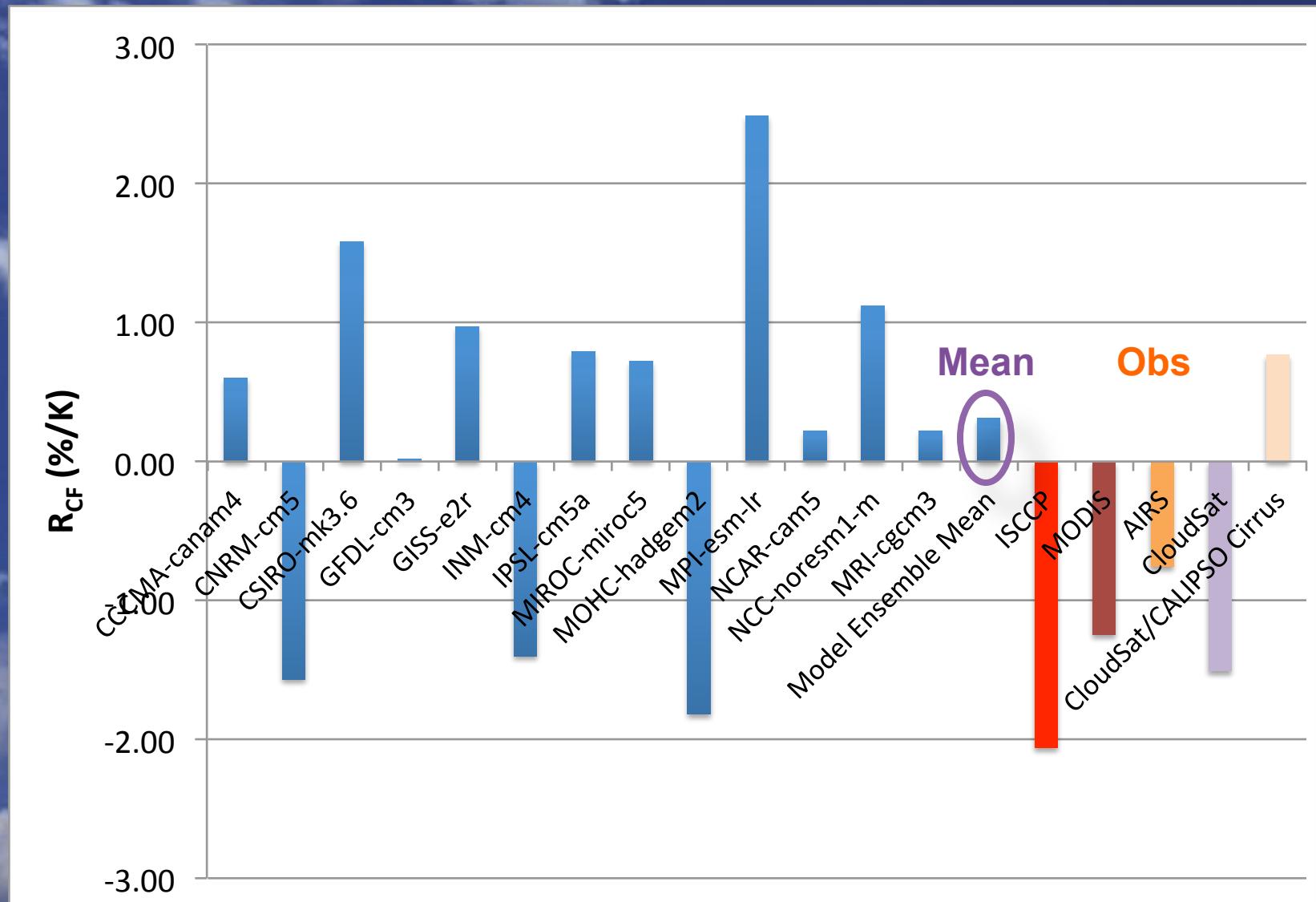


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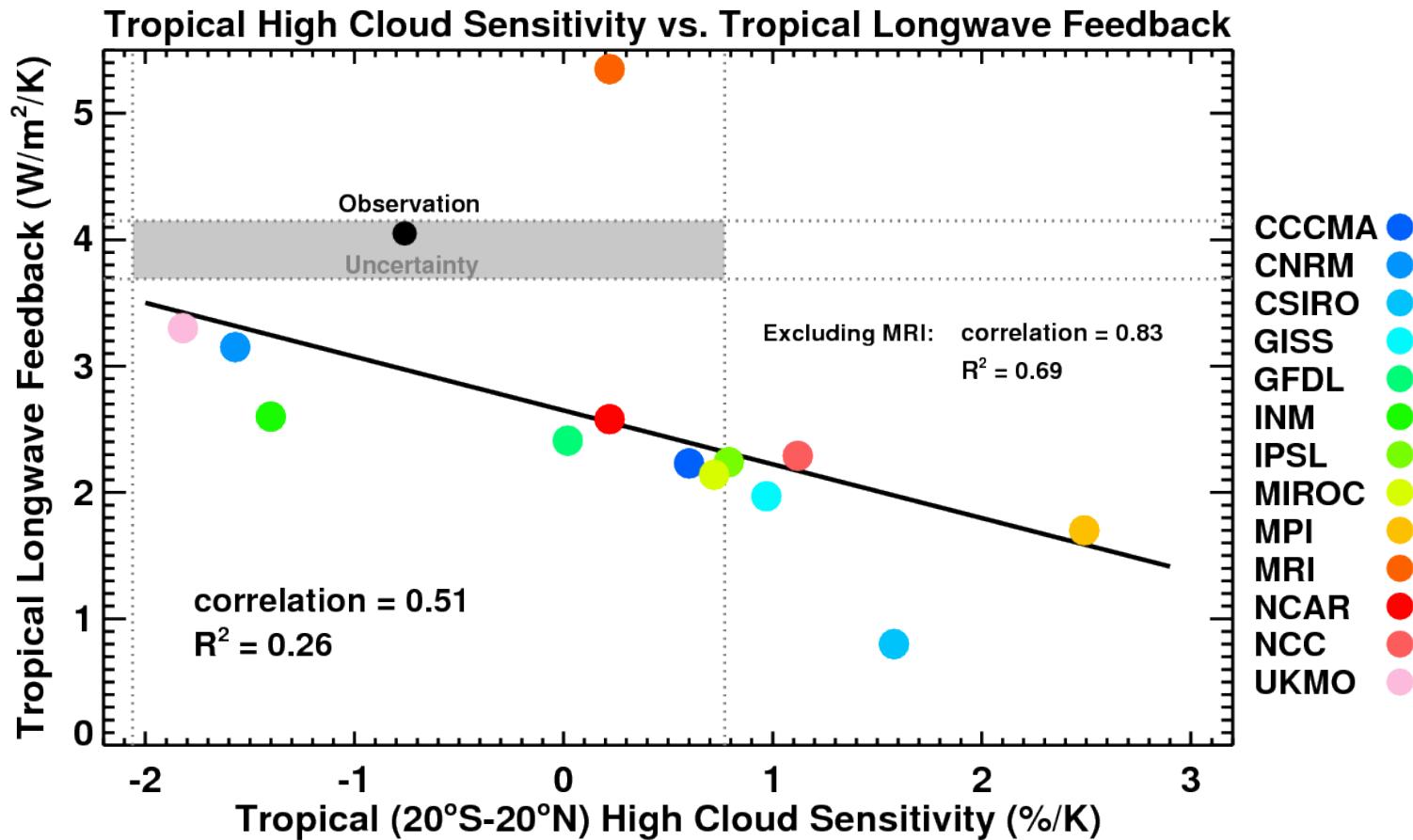


Obs

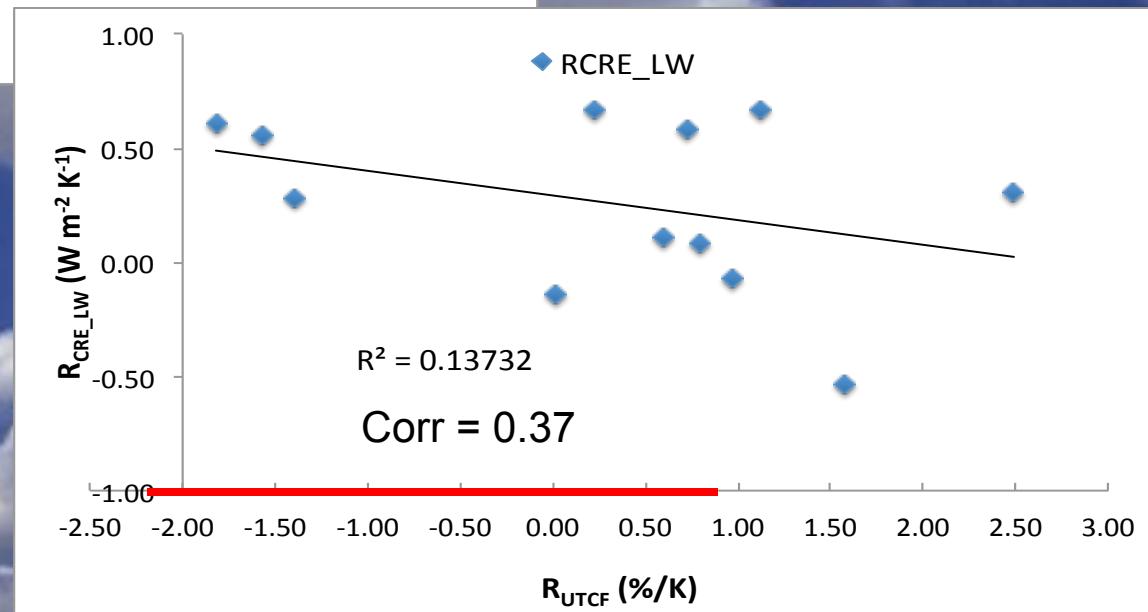
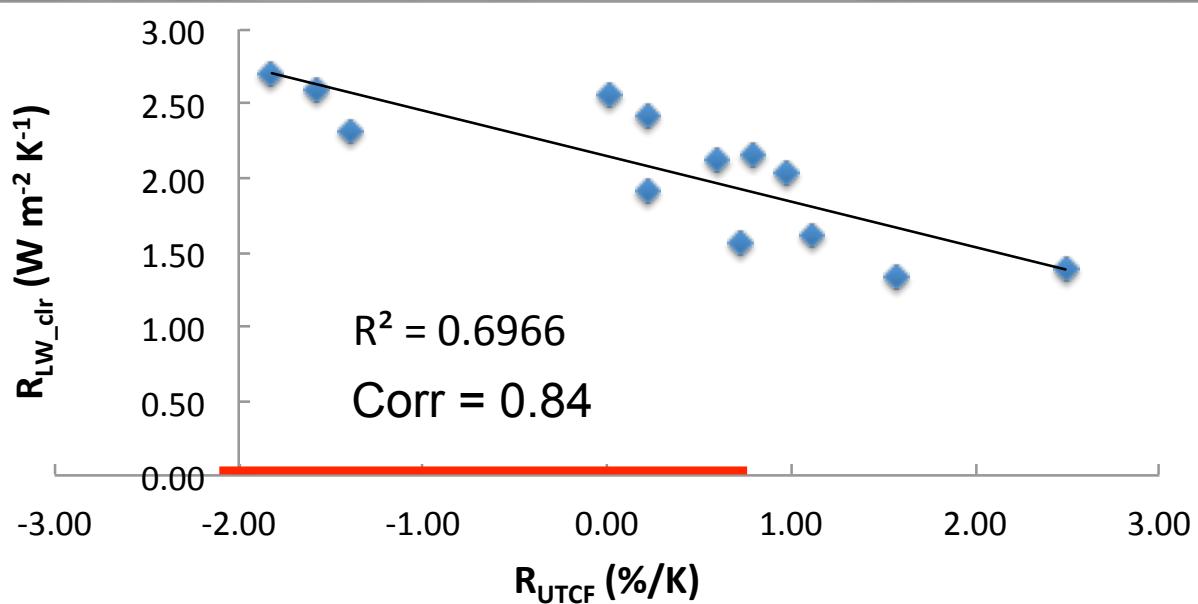
# Tropical High Cloud Fraction Sensitivity to $T_s$



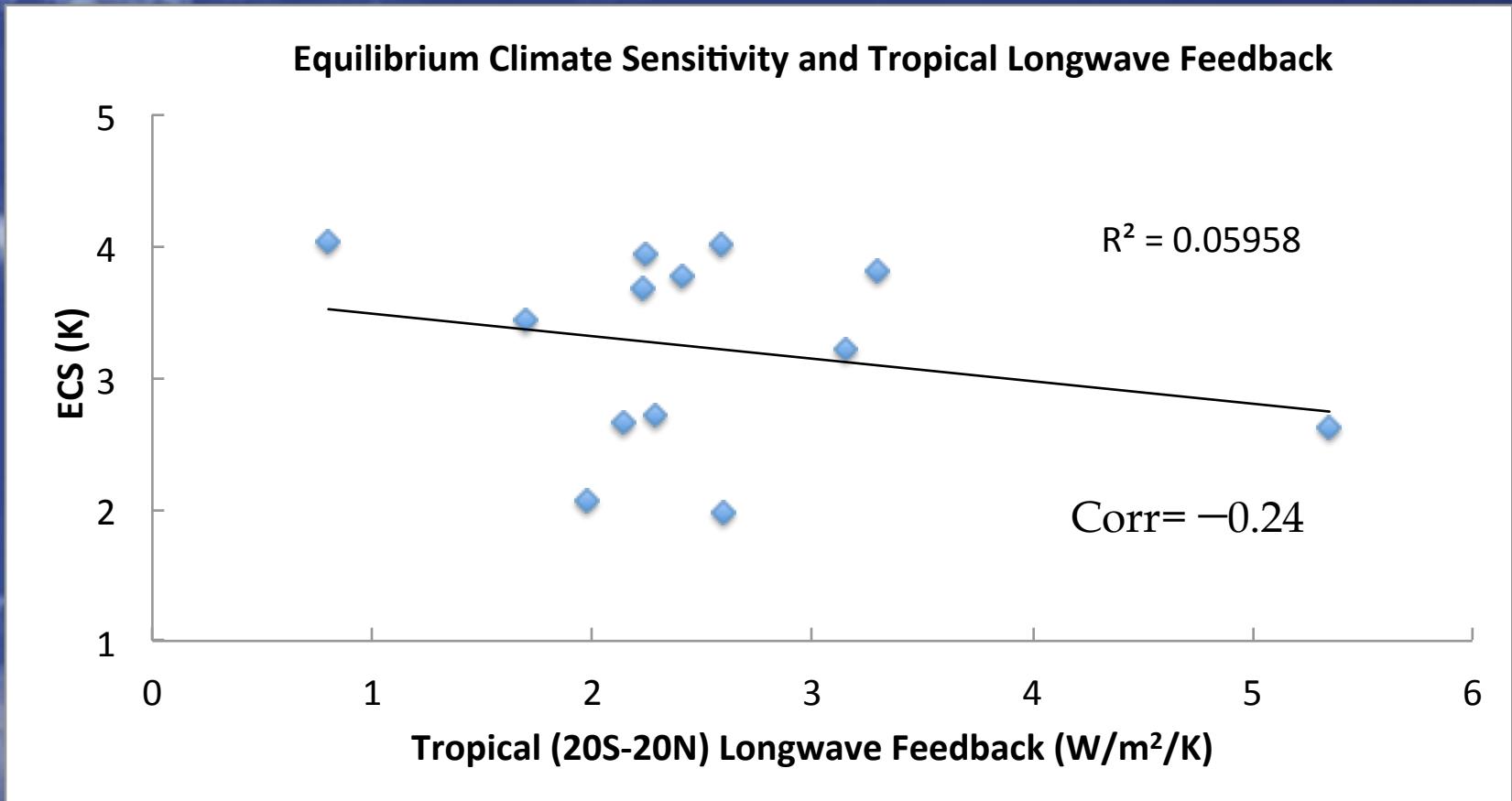
# Tropical High Cloud Fraction Sensitivity and Longwave Feedback



# Separating Clear-Sky and Cloudy Regions

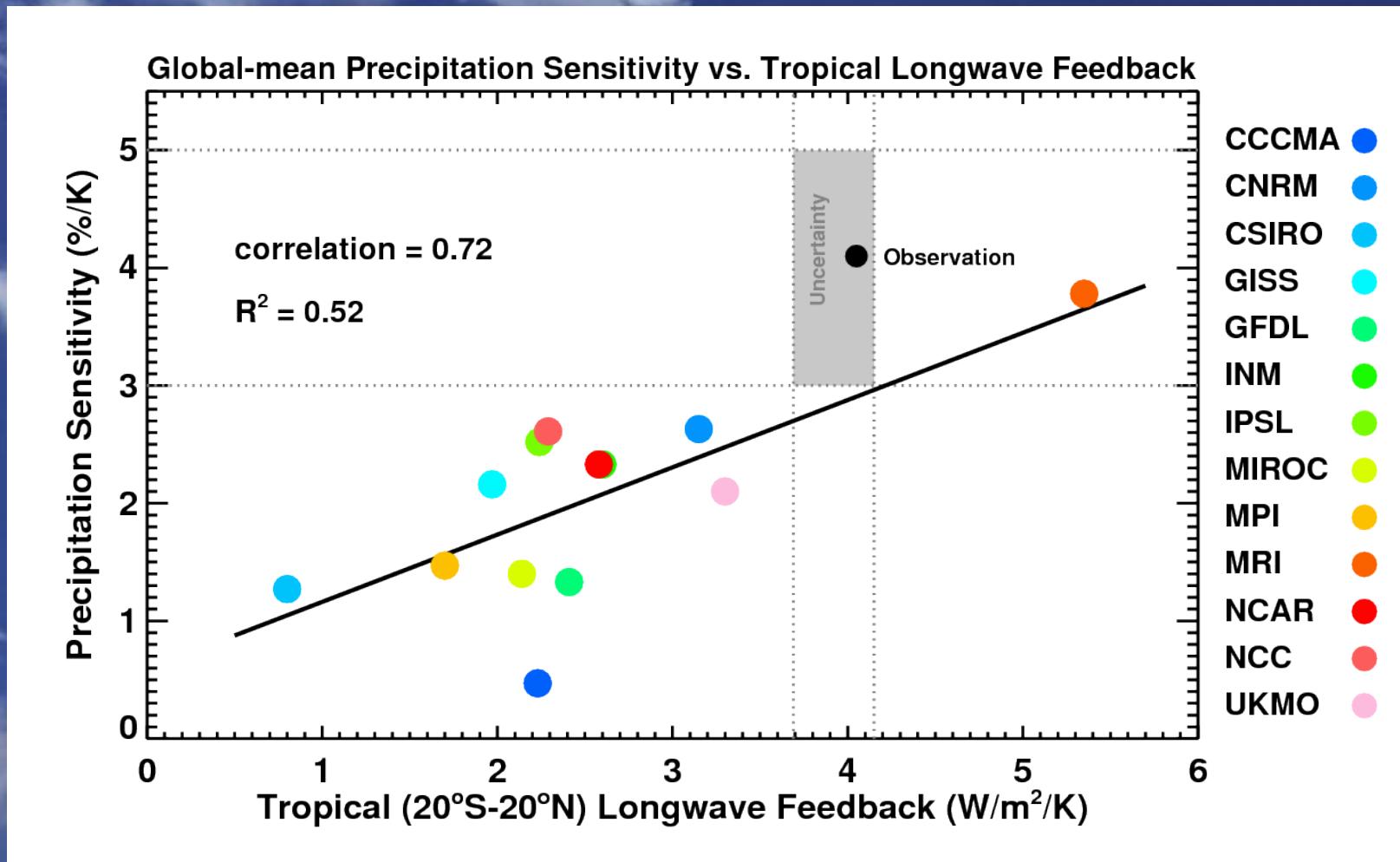


# Tropical LW Feedback and Climate Sensitivity



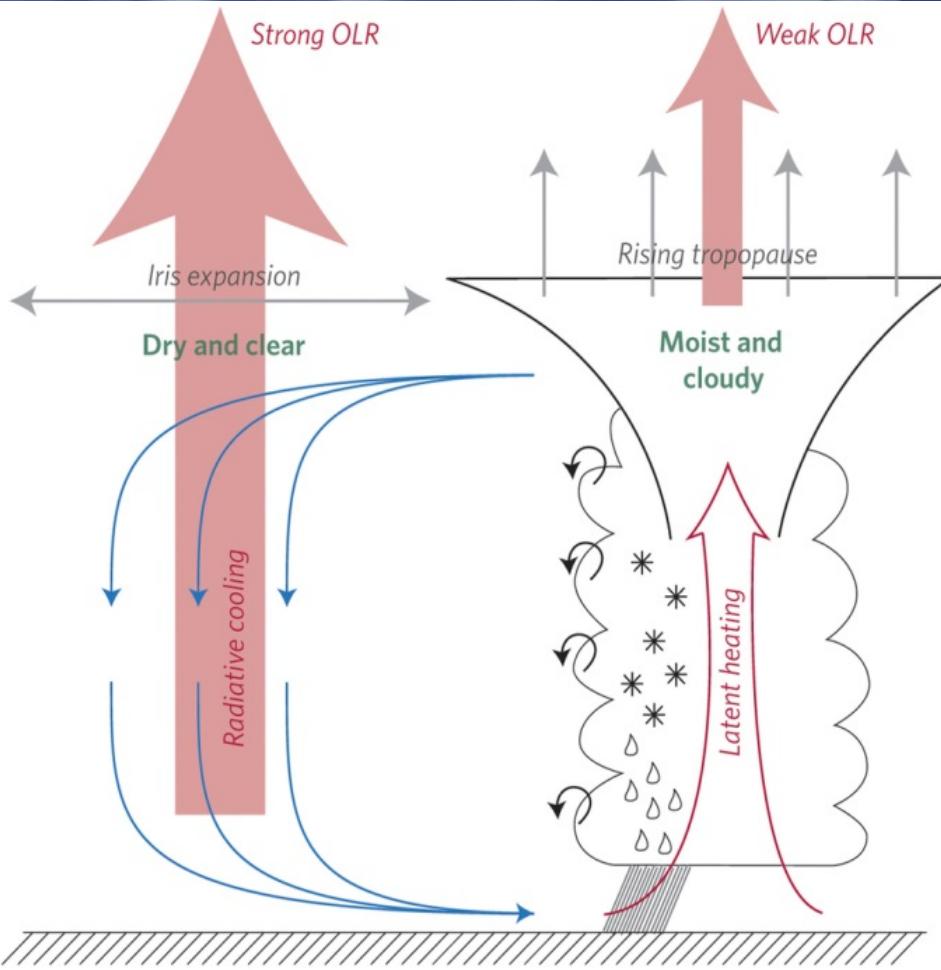
Inter-model spread in tropical longwave feedback is not correlated with models' equilibrium climate sensitivity.

# Tropical LW Feedback and Global Precipitation Sensitivity

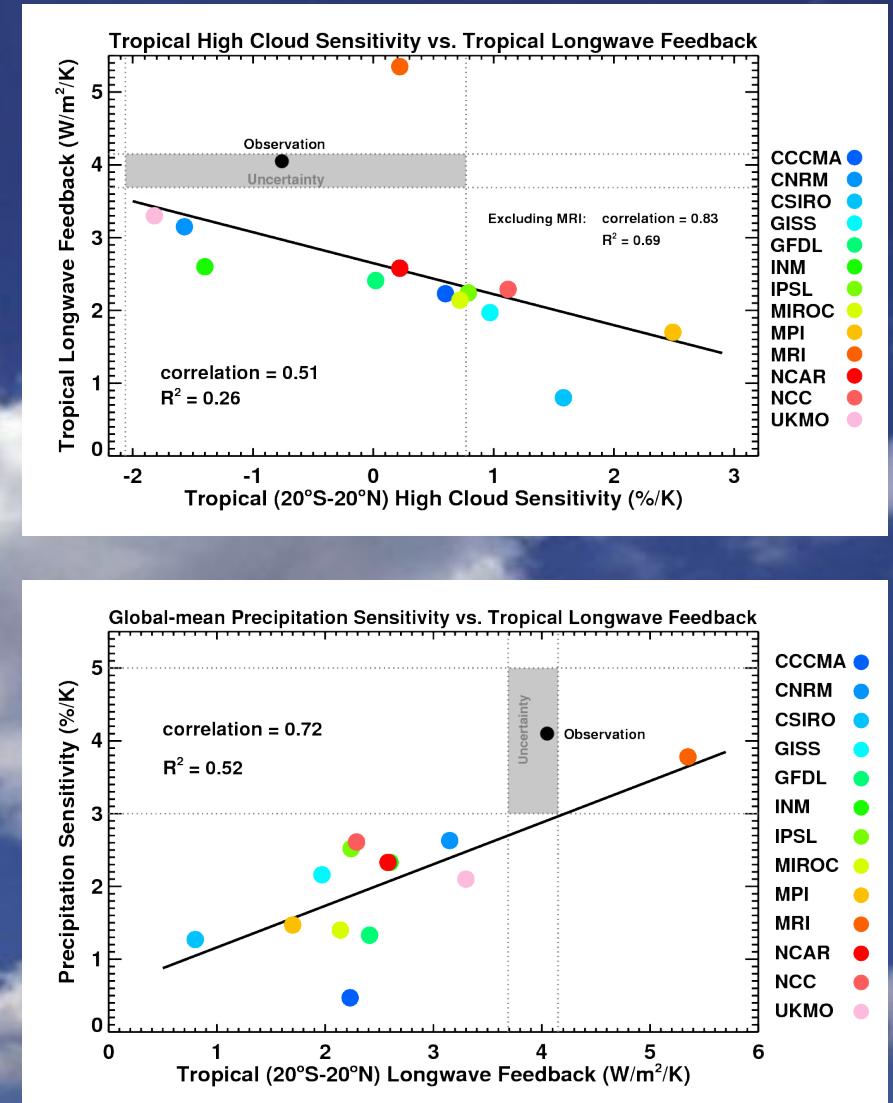


Inter-model spread in tropical longwave feedback is highly correlated with models' global hydrological sensitivity.

# Implications for Hydrological Sensitivity



Mauritsen and Stevens (2015)



# Summary

- Clear-sky outgoing longwave radiation and longwave cloud radiative effects contribute comparably to the muted tropical longwave feedbacks in AMIP5 models.
- Inter-model spread in tropical high cloud sensitivity to surface warming explains a large fraction of the inter-model spread in longwave radiative feedback.
- Inter-model spread in the tropical longwave feedback has little correlation with the spread in models' equilibrium climate sensitivity, but it has a strong correlation with global-mean precipitation sensitivity.